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GLOSSARY OF TERMS USED FOR INTERPRETATION OF WELDS AND CASTINGS RADIOGRAPHS

(First Revision)

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GLOSSARY OF TERMS USED FOR INTERPRETATION OF WELDS AND CASTINGS RADIOGRAPHS

(First Revision)

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GLOSSARY OF TERMS USED FOR INTERPRETATION OF WELDS AND CASTINGS RADIOGRAPHS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 7 October 1985, after the draft finalized by the Non-destructive Testing Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was first published in 1964 covering the definition of the terms used in radiographic inspection of castings. In this revision, definitions of some of the terms have been modified in the light of the latest knowledge in this field, definitions of terms relating to weld radiographs have been incorporated and the title of the standard has been modified.

0.3 The terms included in the standard are generally used to identify various types of discontinuities in castings and welds as revealed by the radiography inspection. These terms are generally correlated with their metallurgical or foundry origin.

0.4 The terms are defined with their possible causes of occurrence and their revealment by radiographic appearance.

1. SCOPE

1.1 This standard defines the industrial terms of the discontinuities of welds and castings as revealed by radiography.

2. WELDS

2.1 Gas Voids

2.1.1 *Gas Voids and Blow Holes* — Gas voids occur in the weld as a result of trapping of gas released from the molten metal or other impurities in the electrode. A gas void of size more than 1·6 mm diameter is called as 'blow hole'.

Radiographic appearance of gas voids may be sharply defined dark shadows varying from circular to extremely elongated or tubular.

2.1.2 *Gas Porosity or Gas Pores* — Gas void under 1·6 mm diameter formed by entrapped gas is termed as gas porosity or gas pore. Radiographic appearance is sharply defined dark shadows of circular contours.

2.1.3 *Elongated Gas Void* — Elongated gas voids appear in the radiograph as dark shadow substantially parallel to the axis of the weld, varying in size and shape.

2.1.4 *Linear Porosity* — A string of gas pores situated parallel to the axis of the weld is termed as linear porosity. Such porosity is frequently accompanied by lack of fusion which may or may not be apparent in the radiograph.

2.1.5 *Worm Hole, Pipe* — An elongated or tubular gas void in the weld metal caused by entrapped gases is termed as worm hole or pipe. It appears in the radiograph as dark shadows, shape of which depends upon the orientation of the discontinuity. If the worm hole is end-on to the radiation beam a dark rounded shadow is produced. Porosity may give a similar appearance but can be distinguished by the defused edges.

2.2 Inclusions

2.2.1 *Slag Inclusions* — Non-metallic solid materials such as slag entrapped during the welding is termed as slag inclusions. This type of discontinuity is more irregular in shape than gas voids. The radiographic appearance of the slag inclusion shows irregular contours with sharp edges and may show variation in density within the image itself.

2.2.2 *Copper Inclusions* — Copper inclusions in the weld may be due to the accidental melting of the contact tube or nozzle in self-adjusting and controlled-arc welding or to pick up by contact between copper nozzle and the weld pool in TIG welding. It appears in the radiograph as a light image of any shape often having indistinct edges due to partial alloying and may thereby be differentiated from a tungsten inclusion.

2.2.3 *Tungsten Inclusion* — Tungsten inclusion in the weld may be due to the inclusion of tungsten from the electrode in TIG welding. It appears in the radiograph as sharp edged light image of any shape.

2.3 Planar Discontinuities (Internal)

2.3.1 *Lack of Fusion or Incomplete Fusion* — This type of discontinuity in the weld may be due to the failure of union between the weld metal and the parent metal, or parent metal and parent metal, or weld metal and weld metal. It appears in the radiograph as dark linear shadow with defined edges. However, depending upon the orientation of the discontinuity with respect to the primary radiation beam, it may tend to be wavy and diffused.

2.3.1.1 *Lack of side wall fusion* — A discontinuity due to the lack of union between weld metal and the parent metal at a side of the weld. The radiographic image appears as dark straight line or bend depending upon the radiation beam direction and may be broken or continuous.

2.3.1.2 *Lack of inter-run fusion* — A discontinuity caused by lack of union between adjacent runs of weld metal in a multirun weld. On a radiograph, it may be revealed as faint line with sharply defined edges.

2.3.1.3 *Lack of root fusion* — A discontinuity caused due to the failure of weld metal to fuse at the root of the weld. It appears in the radiograph as dark line along or near the centre of the weld image.

2.3.2 *Lack of Root Penetration* — It is due to the failure of the root pass to extend into the root of the joint. It appears in the radiograph as a dark defined continuous or intermittent line which may be straight or irregular.

2.3.3 *Crack* — Cracks are linear discontinuities caused due to fracture of the metal in the weld. They may be longitudinal, transverse, edge, centre line, fusion zone, or in parent metal. They are revealed on the radiograph as fine dark lines. Detection of a crack is dependent on its orientation relative to the source of radiation. Divergence from the optimum orientation results in a broadening of the shadow which may become difficult to recognize or is entirely lost.

2.4 Diffraction Mottling — It is an effect produced on a radiograph due to the diffraction of the radiation by large sizes of grains in the metal. Indication on the radiograph is by appearance of diffused light and dark spots or streaks extending over the area. Mottling is often confused with microporosity and segregation.

2.5 Surface Discontinuities

2.5.1 *Incompletely Filled Grooves* — A continuous or intermittent channel on the weld surface running along its length, due to insufficient weld metal. On a radiograph, it appears as a dark bend or dark patches within the weld image.

2.5.2 *Root Concavity or Suck Back* — A shallow groove which may occur in the root of the weld. It would appear on the radiograph as areas along the centre of the weld varying in density according to depth of the imperfections.

2.5.3 *Shrinkage Grooves* — A shallow groove caused by contraction of the metal along each side of the penetration bead. On the radiograph, it appears as a dark band varying in density according to its depth. It should not be confused with undercut.

2.5.4 *Undercut* — An irregular groove at a toe of a run in the parent metal due to welding. It appears on the radiograph as irregular bend in position adjacent to the toe of a weld run.

2.5.4.1 *Root undercut* — Root undercut, caused by melting of base metal at the root, appears on the radiograph as relatively straight and narrow dark lines.

2.5.5 *Excess Penetration Bead* — Excessive weld metal protruding through the root of a fusion weld made from one side only, appears on the radiograph as continuous or intermittent irregular band having lower density within the image of the weld.

2.5.5.1 *ICICLE* — Melting of metal away from the root of the weld appearing on the radiograph as circular light indications.

2.5.6 *Burn-Through* — A localized collapse of weld pool due to excessive penetration resulting in a hole in the weld run is termed as 'burn-through'. It appears on the radiograph as globular dark area. If the hole is incompletely filled, it is revealed as a central dark area. Nonmetallic inclusions are often associated with this type of discontinuity.

2.5.7 *Crater Pipe* — A depression due to shrinkage at the end of a run where the source of heat was removed is called as 'crater pipe'. It appears on the radiograph as a dark circular or elliptical shadow of graduated density.

2.5.8 *Spatters* — Globules of metal expelled during arc welding on the surface of the parent metal results in spatters. These appear on the radiograph as small light spots within the image of parent metal. It may appear on the weld also.

2.5.9 *Surface Pitting* — Imperfection on the surface such as small depressions close to the weld can be mistaken for weld discontinuity. It appears on the radiograph in the image of parent metal but also encroaches on weld image area in asymmetric welds.

2.5.10 *Weld Reinforcement* — Excessive reinforcement of metal on the face of the weld is considered undesirable in specialised applications. This is indicated on the radiograph as appearance of white shadow covering the weld image.

2.6 Some of the important weld discontinuities are illustrated in photographs of typical radiographs. These illustrations are intended solely to be complimentary to the definitions of the defects and should not be considered as criterion of their severity. These are given as Fig. 1 to 9 in Appendix A.

3. CASTING DISCONTINUITIES

3.1 Gas Voids

3.1.1 *Gas Holes* — Gas holes are the voids produced in the coating due to entrapment of the gas released from the melt itself, or from core, sand moulds or from other causes, namely, turbulance during pouring of metal. A discrete cavity greater than about 1·6 mm diameter is termed as 'blow hole'. A particular form of 'worm-hole' occurs as a tube-like cavity usually normal to and almost reaching to the surface of the casting.

Radiographic appearance of 'gas hole' shows as dark area of smooth outline which may be circular or elongated. Worm-hole appearance may vary from a circular to an extremely elongated image depending on the angle of view.

3.1.2 *Gas Porosity* — The gas porosities in a casting are the small voids of size less than 1·6 mm diameter, formed due to entrapment of gas as stated in **3.1.1.** Usually the porosities are due to the evolution of dissolved gas fromthe molten metal and occurring either throughout the casting or localised within a particular area. When localized near the surface, for example, due to gas evolved at the mould face, it is called subcutaneous pinhole porosity.

Radiographic appearance shows an assemblage of small, rounded, widely distributed dark images.

3.1.3 *Airlock* (*Entrapped Air*) — A void formed by air which has been trapped in the mould by the metal during pouring.

The discontinuity appears in the radiograph as a dark area with an outline which is generally smooth. An airlock cannot always be distinguished radiographically from a gas hole but a helpful guide to identification is the shape, size and position in the casting.

In pressure die casting air may be injected with the metal; in this instance the defect is usually more severe in the runners and may assume an angular form. In both pressure and gravity die casting the defects may occur as cluster or strings of small voids.

3.2 Shrinkage

3.2.1 *Shrinkage Cavity* — A discrete cavity caused by contraction of metal during solidification. A particular type of shrinkage associated with blockage of feeding head is commonly referred to as 'piping' although it is not necessarily tubular.

Radiographic appearance is similar to that of gas hole but usually shows a less regular outline and may tend to taper. Occasionally, it may be difficult to distinguish between the two. Piping is usually identified when the position of the feeding head is known.

3.2.2 *Shrinkage Porosity or Sponginess* — A system of interdendritic cavities of a coarse and usually localized form. The discontinuity usually appears in a radiograph as a group of dark interconnected images which may be irregular in outline and of varying size and blackness.

3.2.3 *Micro-shrinkage* (*Magnesium Base Alloy*) — A fine form of discontinuity due to shrinkage, gas or both in which a number of cavities occur either around the grain boundaries (intercrystalline) or between the dendrite arms (interdendritic). These cavities tend to link up in a three-dimensional network throughout the metal. In the radiograph, the dark images of these cavities are superimposed and usually produce a general mottled or cloudy effect. In non-ferrous alloys, particularly those with a magnesium base, the fine cavities may occur in layers (layer porosity) and produce dark streaks in the radiograph.

NOTE — The radiographic appearance of the defect can often be confused with that of diffraction mottling and action should be taken to verify the interpretation.

3.2.4 *Filamentary Shrinkage* — A coarse form of shrinkage discontinuity in which the voids are branching, interconnected and extensive, occasionally the discontinuity may be of dendritic form.

In the radiograph images appear as continuous, irregular dark lines usually branched or occasionally in the form of a network; the line may become very fine. This type of discontinuity, in some cases, have a similar radiographic appearance to layer porosity.

3.3 Heterogenetics

3.3.1 *Inclusions* — Foreign materials entrapped in casting may be sand, clay, flux, dross, oxide, or metal of different density. It appears as isolated, irregular, or elongated variation of film density neither corresponding to variations in thickness of material nor to voids.

An inclusion may be of greater or lesser opacity than the surrounding metal. It may appear radiographically either as light or dark area, for example, a sand inclusion in steel will appear dark in the radiograph whereas in magnesium alloy, it will appear light. Slag usually gives a rounded image, whereas material included in the casting as a solid, for example, dross and sand, will give an image of irregular shape; thus dross trapped as an oxide film, often produces a characteristic folded appearance. The discontinuity may be at times difficult to distinguish from a void or segregation, but there are usually more variations in density across the image of an inclusion.

3.3.2 *Segregation* — A condition resulting from non-uniform distribution, usually a concentration of certain constituents or impurities or both, arising during freezing and generally persisting through subsequent operations. It may be classified as general, localized or banded. Its radiographic detection depends upon the segregating constituents producing a local variation in the absorption of radiation.

NOTE — General or banded segregation may be a normal feature of certain castings and these should not be considered as defects.

3.3.2.1 *General segregation* — Segregation extending a considerable part of casting and taking a variety of forms, for example, inter-crystalline segregation. Radiographically it appears as an assemblage of small-light or dark areas. An extreme form of inter-crystalline segregation in which the segregating constituent entirely surrounds the grains of the parent metal is known as boundary film.

The presence of numerous small segregates may produce a flocculant appearance in the radiograph which may be confused with micro-porosity or diffraction mottling. The defect may also appear as randomly oriented streaks, each consisting of an adjacent dark and light hand.

3.3.2.2 *Local segregation* — Segregation occurring when shrinkage voids or hot tears are wholly or partially filled with a constituent of low melting point; the terms 'shrinkage segregation' and 'hot tear segregation' can be applied respectively to these two conditions. The segregates appear in the radiograph as light or dark areas coinciding with the original discontinuity. In some examples, however, where the discontinuity is only partially filled there may be adjacent light and dark areas within the original outline.

3.3.2.3 *Banded segregation* — Segregation associated mainly with centrifugal castings but occasionally occurring in static castings. It takes the form of alternate layer of the alloy enriched in or depleted by the separating constituents. Radiographically, it appears as alternate dark and light bands.

3.4 Sharp Discontinuities

3.4.1 *Crack* — A discontinuity due to the fracture of the metal during or after solidification. The discontinuity appears in the radiograph as one or more dark lines whose width and form depends upon the type of crack and particularly upon the radiographic technique used.

3.4.1.1 *Hot tears* (*cracks*) — A discontinuity generally of a decidedly rugged form resulting from stresses developed near the solidification temperatures when the metal is weak; these stresses usually arise when the contraction of the casting is restrained by the mould or the cores. The discontinuities occur mainly at or near the change of sections. The discontinuities are not definitely continuous, may exist in groups and often terminate at the surface. In iron and steel industry, it is referred to as 'pull'.

Radiographically a hot crack is revealed as rugged dark lines of variable widths and numerous benches. They have no definite line of continuity and may exist in groups. They may originate internally or at the surface. Generally the ends taper and become fine.

The radiographic appearance may resemble that of filamentary shrinkages or certain types of cold cracks.

3.4.1.2 *Stress crack* — A well defined and approximately straight crack formed when the metal has become completely solid, quite large stresses being required to cause fracture. Distinctions are sometimes drawn between types of this discontinuity, depending upon the time at which the fracture occurred for example, stress crack due to contraction, residual stress. shock or service.

In the radiograph a crack is often revealed as a clearly defined smooth dark line, thus differing from the rugged appearance of a hot tear.

By reasons of their origin, different types of stress cracks are often similar in appearance and indistinguishable radiographically. In certain instance, however, a characteristic form may be shown. Examples of these are grinding cracks in steel giving a crazed pattern, heat treatment cracks, often star shaped and trans-crystalline fractures, showing typical loops.

3.4.2 *Cold Shut* — A discontinuity caused by the failure of a stream of molten metal to unite with either a confluent stream or a solid metal such as chaplet, internal chill or pouring splash.

In radiograph, cold shut appears as distinct dark line or a band of variable length and definite smooth line. It may be difficult to distinguish from a hot tear except of the discontinuity. The shape of the image of an unfused chaplet or unfused chill (including nailhead) is dependent upon the orientation of the beam of radiation A cold shut arising from a splash in the mould may appear as a dark crescent or circle.

3.5 Miscellaneous

3.5.1 *Surface Irregularities* — It is any image on the radiograph corresponding to 'irregularity' visible on the surface.

3.5.2 *Misrun* — These occur in castings when molten metal fails to fill the mould completely and appear as prominent darkened area of variable dimensions with a definite smooth outline.

3.5.3 *Coreshift* — Appears as a variation in wall thickness.

APPENDIX A

(*Clause* 2.6)

ILLUSTRATIONS SHOWING TYPICAL WELD DISCONTINUITIES

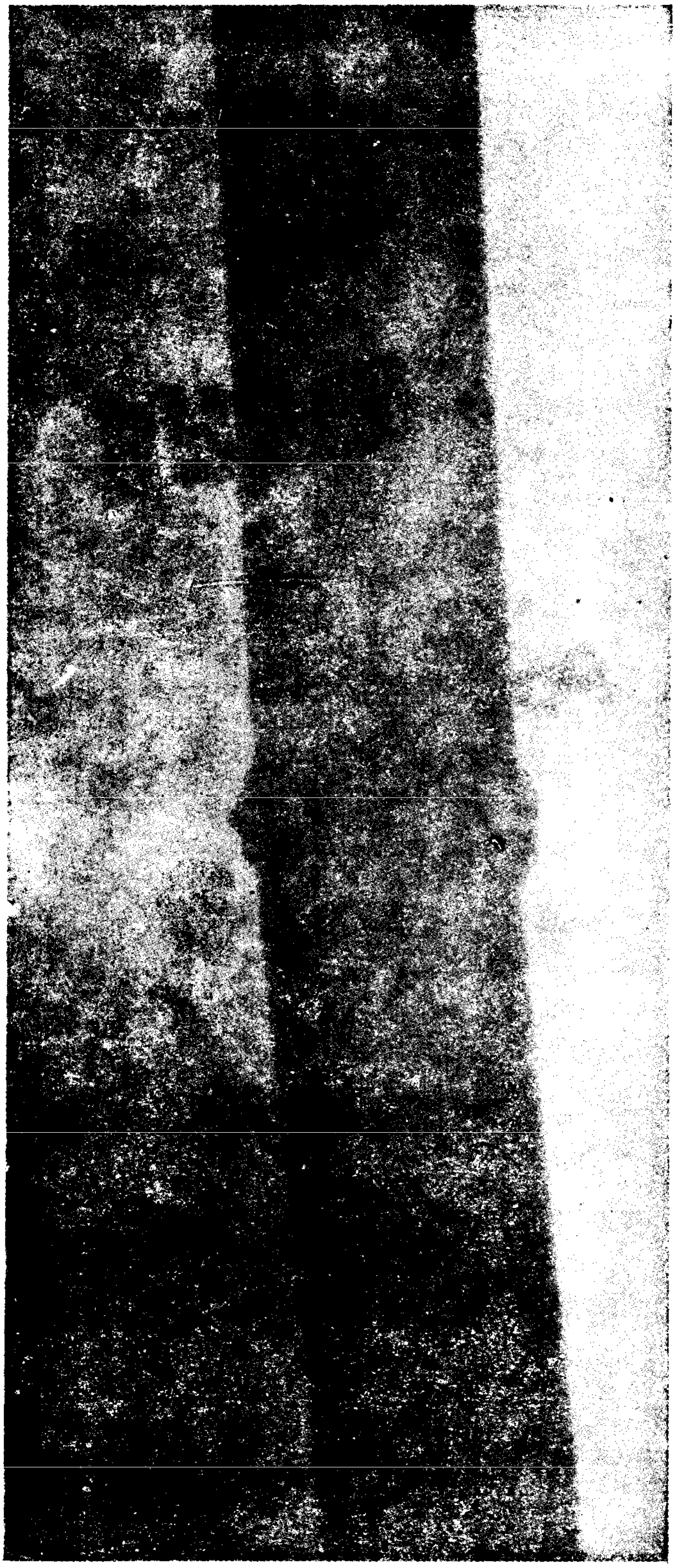

Fig. 1 A Typical Radiograph of Welded Joint of Waste Heat Boiler Tube Showing no Defect

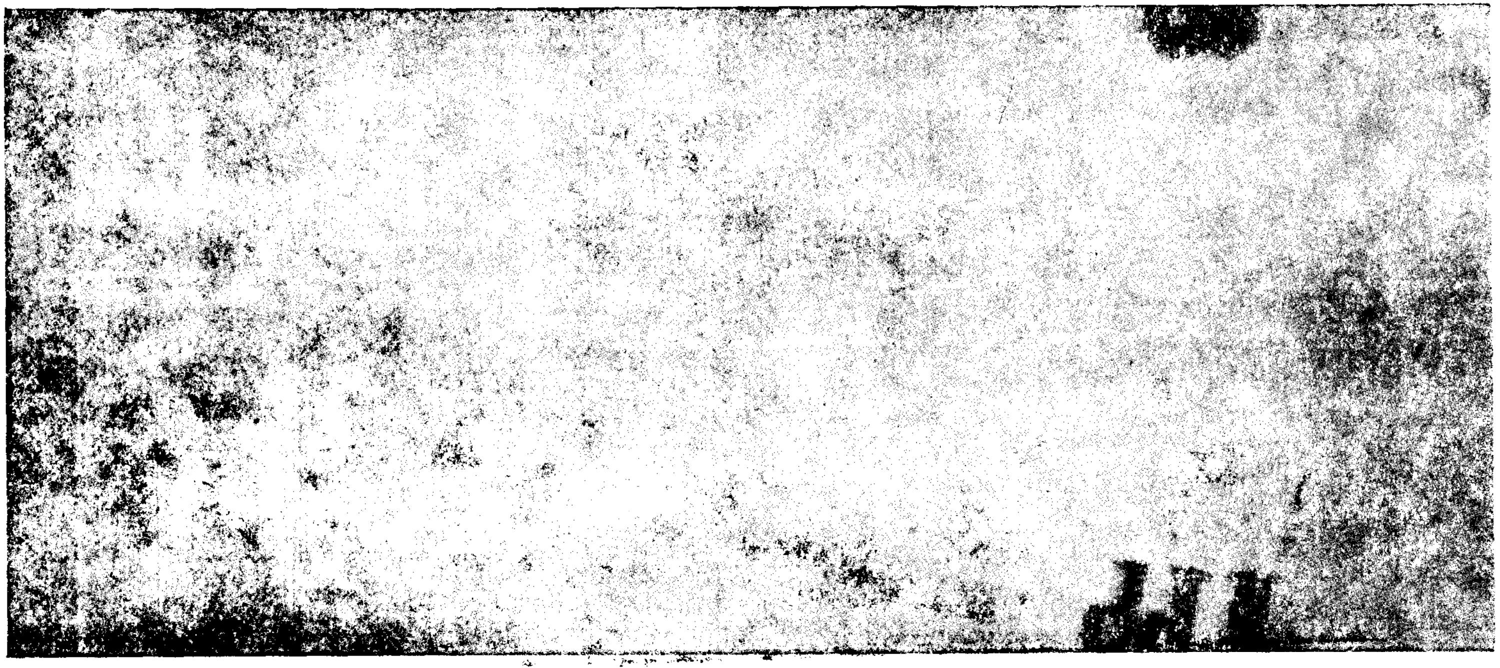

FIG. 2 A TYPICAL RADIOGRAPH OF WELDED JOINT OF STEAM PIPE LINE SHOWING LACK OF FUSION (FULL LENGTH)

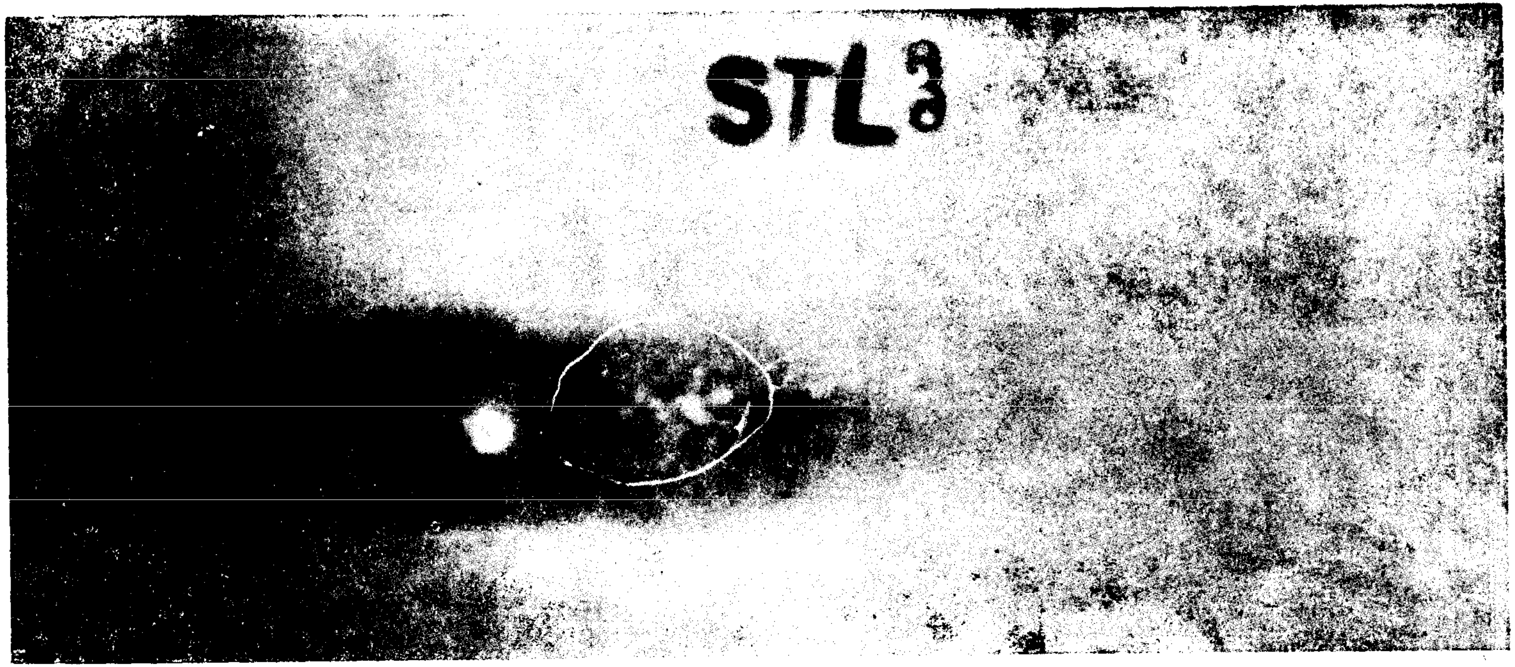

FIG. 3 A TYPICAL RADIOGRAPH OF WELDED JOINT OF RAIL TONG STRUCTURE SHOWING HEAVY POROSITIES IN BUNCHES THROUGHOUT THE LENGTH

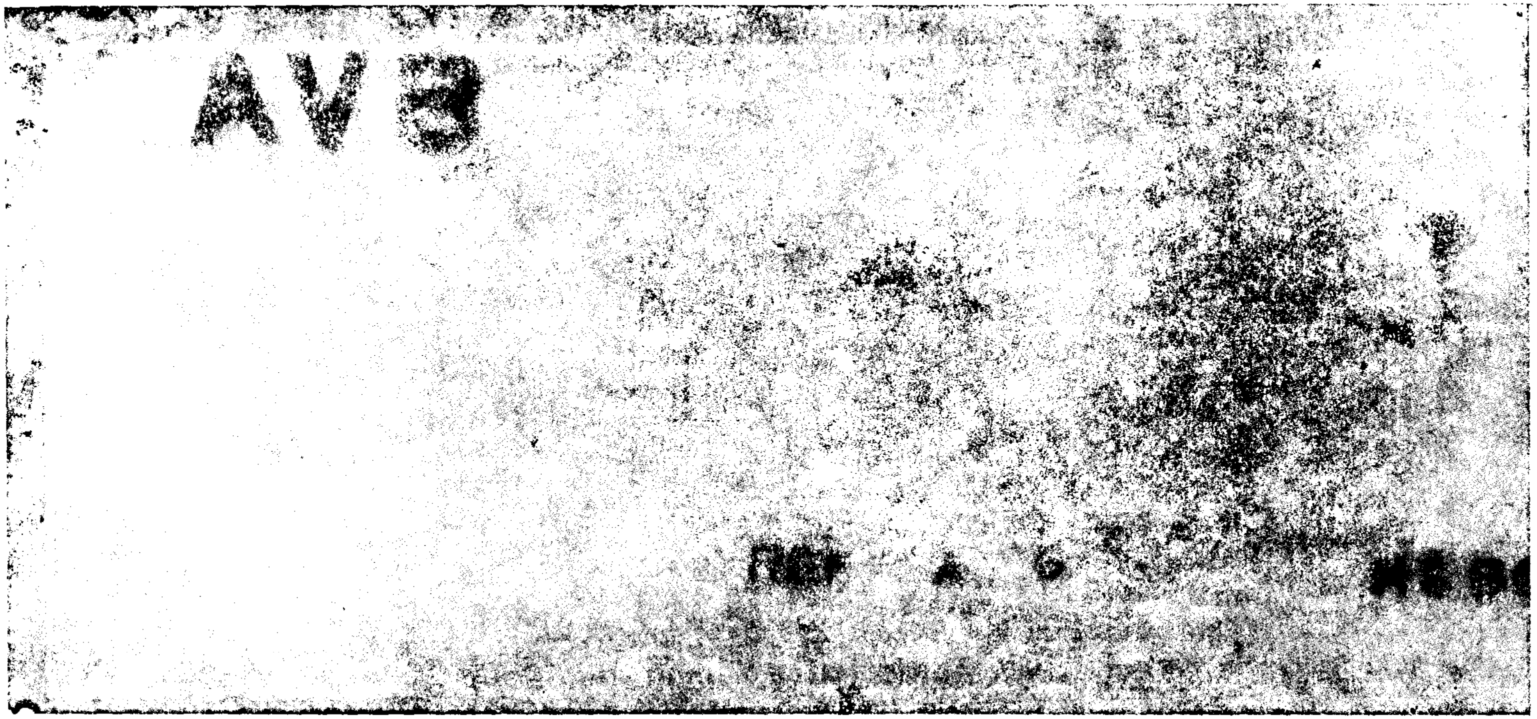

FIG. 4 WELD DEFECTS — CRACKS AND BLOW HOLES

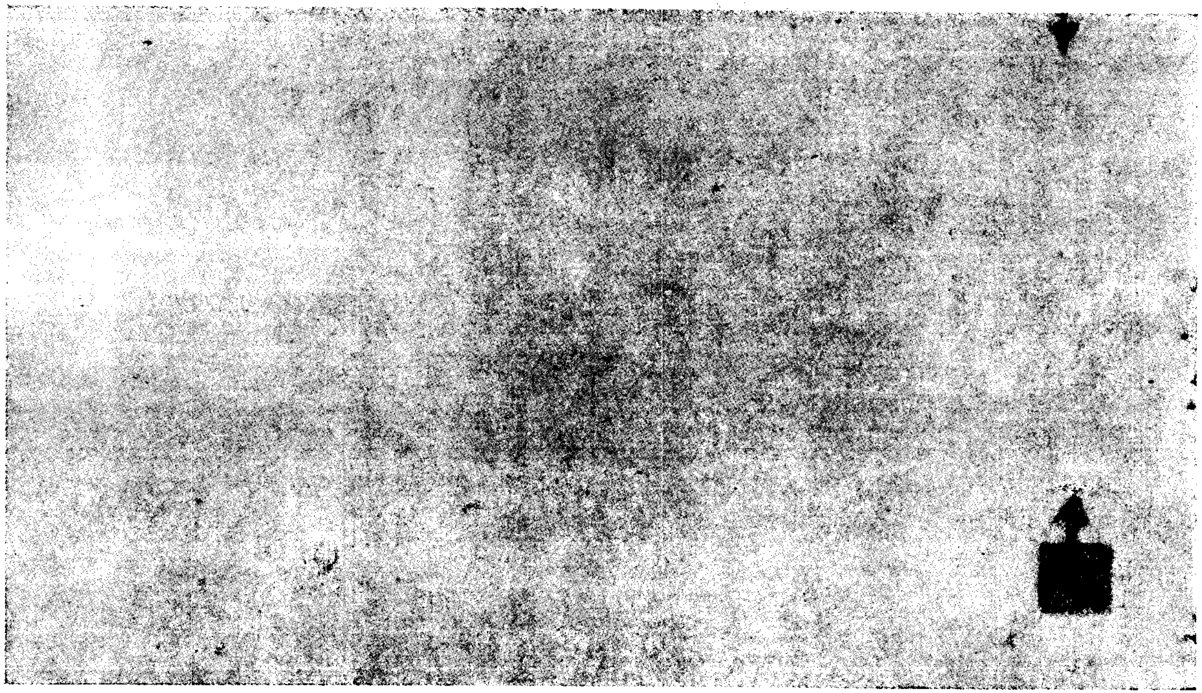

FIG. 5 WELD DEFECTS — SLAG LINE

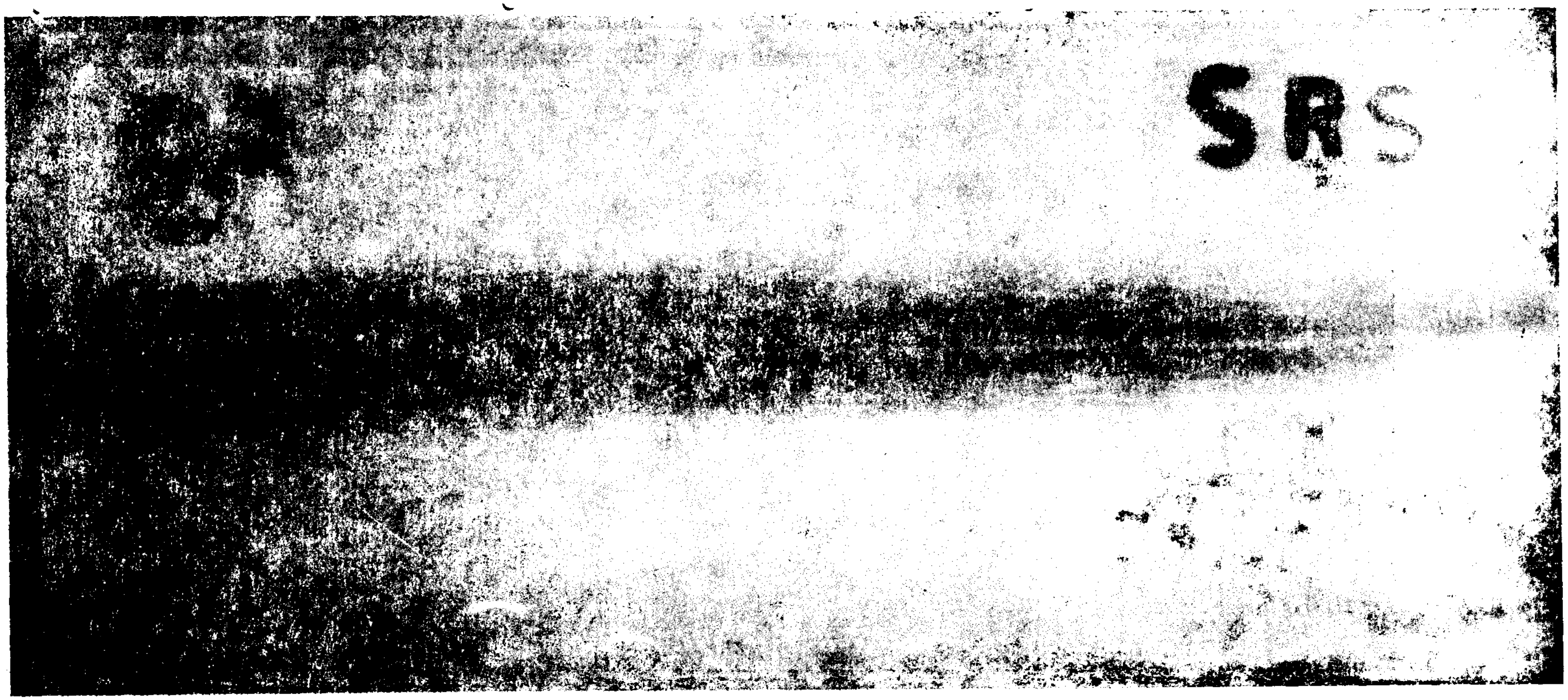

Fig. 6 A Typical Radiograph of Welded Joint of Steel Plates Meant for Blast Furnace Uptakes, Showing Incomplete Penetration (Full Length)

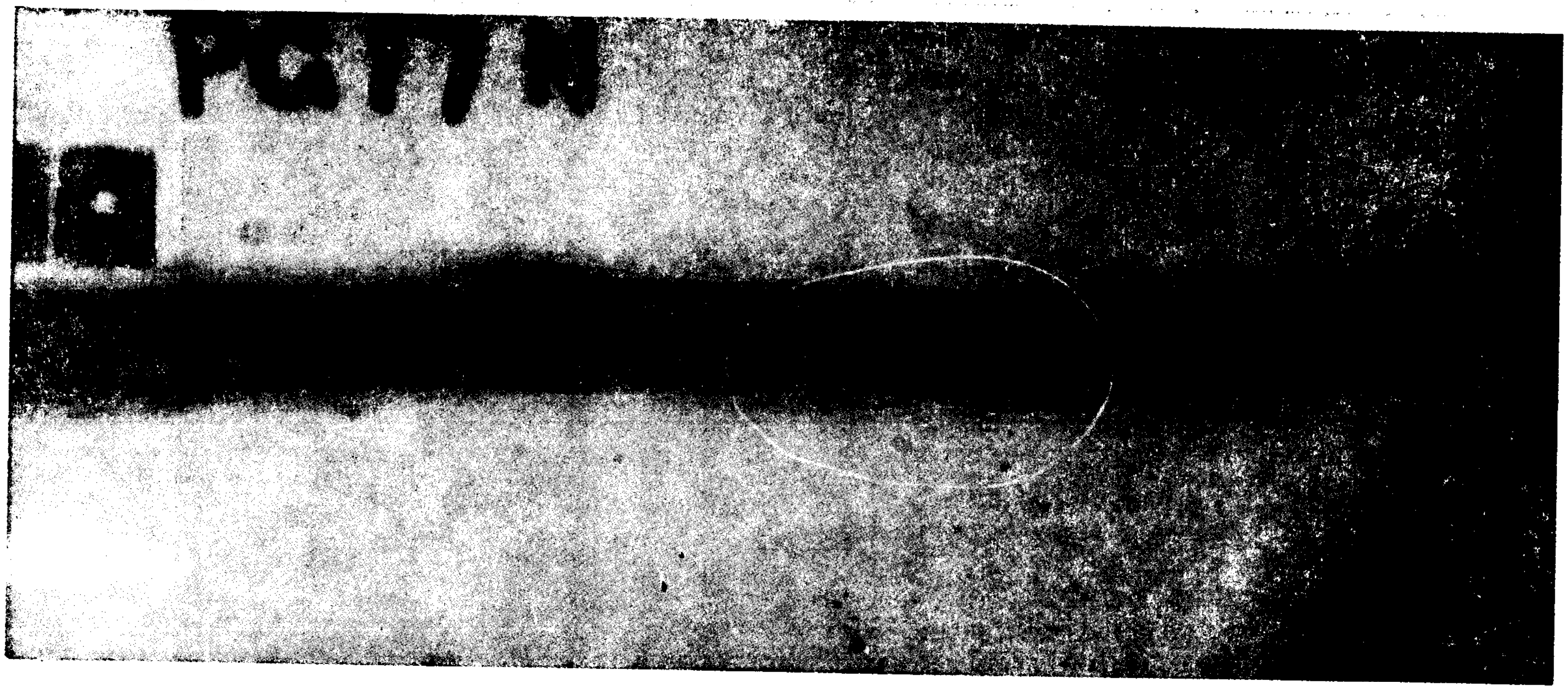

FIG. 7 A TYPICAL RADIOGRAPH OF WELDED JOINT OF CRANE GIRDER SHOWING CHAIN TYPE POROSITIES (70 mm LENGTH)

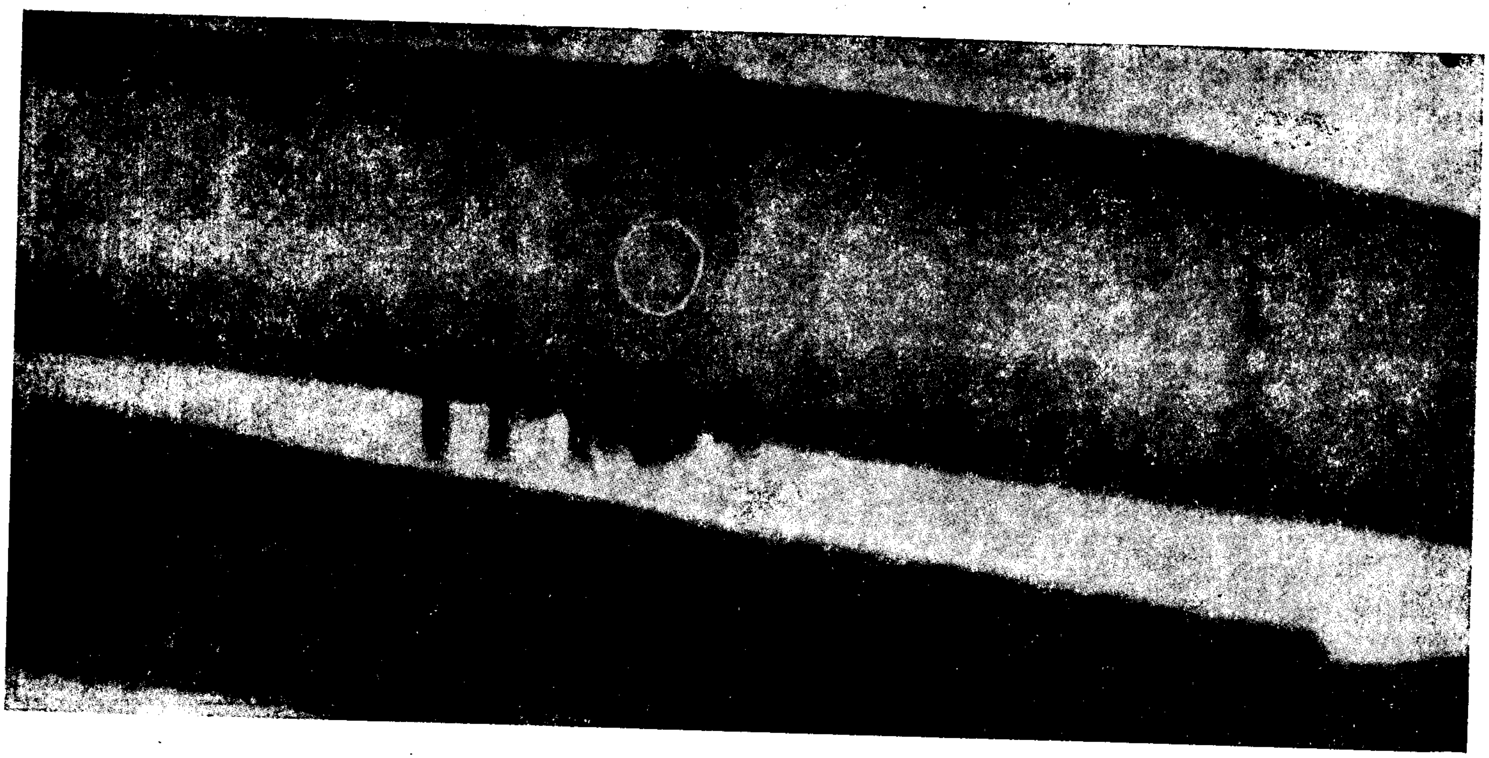

FIG. 8 A TYPICAL RADIOGRAPH OF WELDED JOINT OF ECONOMISER OF BOILER SHOWING BIG VOID

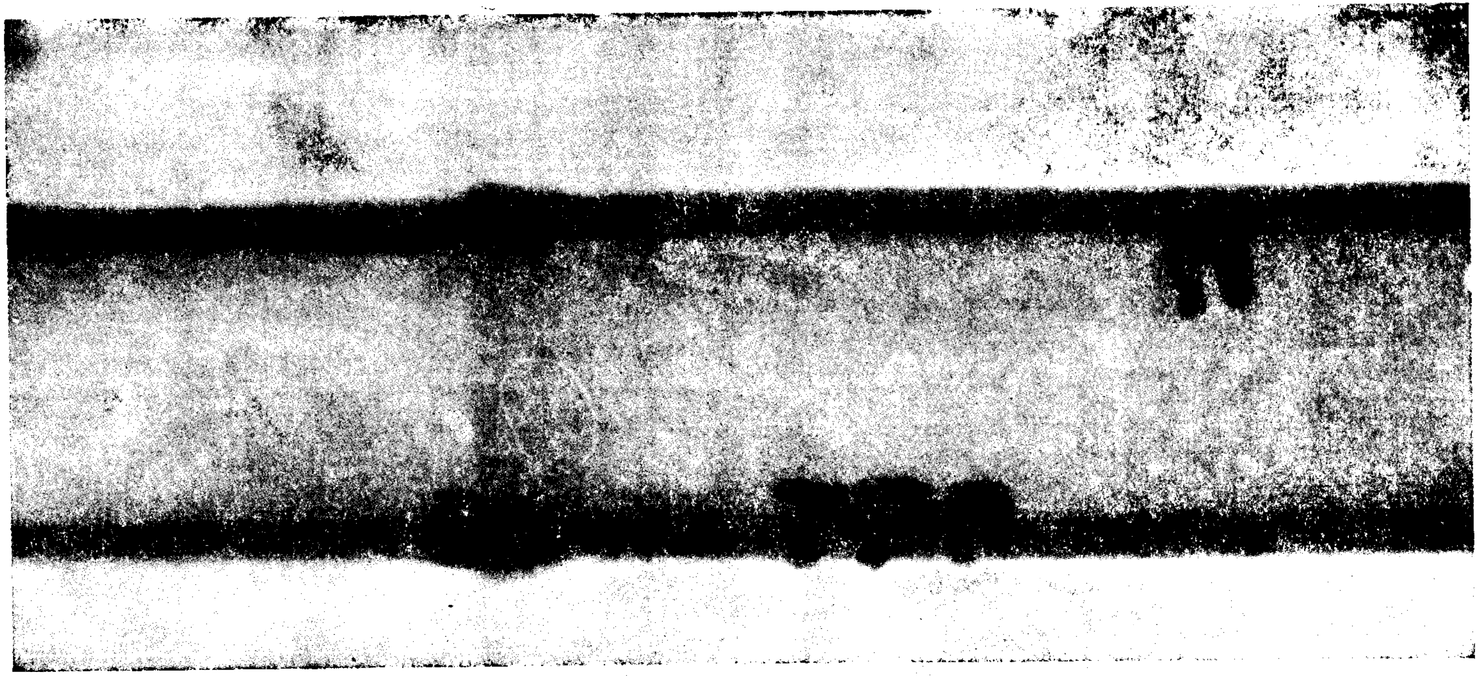

Fig. 9 A Typical Radiograph of Welded Joint of Suepr-Heater Tube of Boiler Showing Slag Inclusion

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